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SIMULATION OF SWITCHING TRANSIENTS OF 90 TR CHILLER SYSTEM AT SASTRA UNIVERSITY

G. Swaminathan and S. Natarajan
School of Electrical and Electronics Engineering, Shanmugha Arts, Science, Technology & Research Academy, Thanjavur, India
E-Mail: swami_3737@yahoo.co.in

ABSTRACT

In the recent years there is growing concern for “Electric Power Quality” with the modern electronics equipments such as UPS, PC’s, variable speed drives and industrial programmable logic controllers are sensitive to the variation of the supply voltage. In particular, motor start applications draw large amount current at the time of starting and contribute to system degradation, particularly in very sensitive area. This switching transient problem was noticed in the 90Ton chiller system of university. Hence this needs modeling the chiller system components and simulating the processes of switching transient. The practical results were analyzed and compared simulation study for evaluating the quality of power in the System. Consequently, this paper investigates the coefficient of performance (COP) of chiller to verify the accuracy.

Keywords: chiller, transients, coefficient of performance.

INTRODUCTION

Apart from harmonics, transient voltage variations resulted from lightning strikes, switching of power line/capacitor bank and voltage sags caused due to system faults and large motor starting are common concerns related to the electric power quality issue. This work is focused on the 90TR chiller system in the animal house building of SASTRA University where the sensitive equipment suffers mal-operation/interruption and power disturbances at the time of starting the chiller system. The feeder is includes chiller, air-conditioners, fluorescent lighting, UPS, PC’s, heaters, compressors, vacuum pump, etc. Some power quality related disturbances were absorbed in the feeder of Animal House distribution system. The pump motors in the central chiller plant tripped occasionally. The auto clave equipment in the animal house building had been put into use and suffered tripping during operation of this chiller. Though no equipment had been severely damaged under such abnormal tripping, the time-consuming reset/restarting process for the instrument caused inconvenience to the operating personnel. The accuracy with which the chiller model can be expected to predict performance is assessed from the goodness of fit obtained. The objective of this paper is to formulate the models of University 90TR Chiller system components and simulate several processes related to power quality problems.

The real time performance monitoring and diagnostics require some form of baseline to define correct operation. This baseline can take the form of a quantitative model that must be configured using measured performance data. This study involving the use of quality performance data suggests that models have the potential to act as accurate baselines for energy performance.

The objective of this paper is to formulate the models of University 90TR Chiller system components and simulate several processes related to power quality problems. The need for simple modal to reject transient data, detect power surges and identify control problems. The accuracy with which the chiller model can be expected to predict performance is assessed from the goodness of fit obtained

PRESENT WORK CHILLER PERFORMANCE

DESCRIPTION

The most commonly used systems for industrial and commercial refrigeration and air conditioning are vapour compression refrigeration system and vapour absorption refrigeration system. vapour compression machines, usually with electrically driven compressors, are the most commonly used machines for air conditioning for temperatures ranging from 23 °C to -70 °C.

Starting at the compressor; the refrigerant is compressed and sent out of the compressor as a high temperature, high-pressure, superheated gas. The refrigerant travels to the condenser (Which is air cooled by fans). The condenser changes the refrigerant from a high temperature gas to a warm temperature liquid. It then travels into the Thermal Expansion valve or TXV. The TXV meters the proper amount of refrigerant into the evaporator. The TXV takes the high pressure liquid and changes it to a low-pressure cold saturated gas. This saturated gas enters the evaporator where it is changed to a cool dry gas (no liquid present). The cool "dry" gas then re-enters the compressor to be pressurized again. The hot gas by pass (unloader assembly) is used to stabilize the cooling output of the refrigeration system by allowing hot gas to warm up the cool evaporator. This causes a reduction in to cooling efficiency and a stabilizing of the chilled water temperatures.

Air conditioning systems cover a wide variety of cooling applications, using both standard and custom-made equipments. This study is about 90Ton Blue star Chiller units used for Animal house building at SASTRA University. Comfort air-conditioning implies cooling of room air to about 24 °C and relative humidity in the range of 50% to 60%.

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SYSTEM EFFICIENCY

The cooling effect of refrigeration systems is generally quantified in tons of refrigeration. The unit is derived from the cooling rate available per hour from 1 ton (1 short ton = 2000 pounds = 907.18 kg) of ice, when it melts over a period of 24 hours. Refrigeration and air conditioning engineers still popularly use British measuring units; hence it is necessary to know the energy equivalents.

1 Ton of Refrigeration (TR) = 3023 kcal/h
= 3.51 kW thermal
= 12000 Btu/hr

PERFORMANCE AND EFFICIENCY

The commonly used figures of merit for comparison of refrigeration systems is coefficient of performance (COP) and defined as

a) If both refrigeration effect and work done by the compressor (or the input power) is taken in the same units (TR or kcal/hr or kW or Btu/hr), the ratio

COP = Refrigeration effect / Work done

Higher COP indicates better efficiency.

VAPOUR COMPRESSION SYSTEMS OPERATING PRINCIPLE

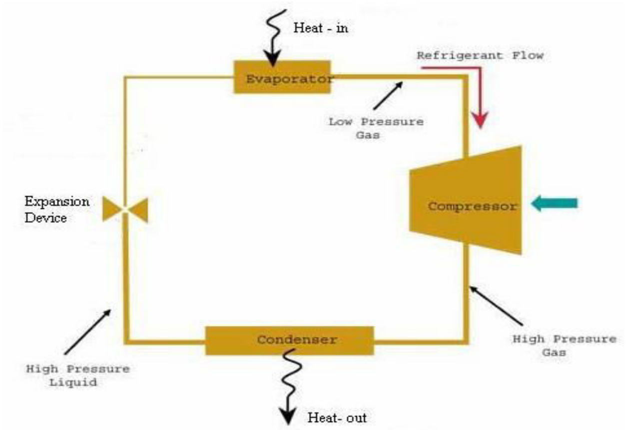

Figure-1. Compression system.

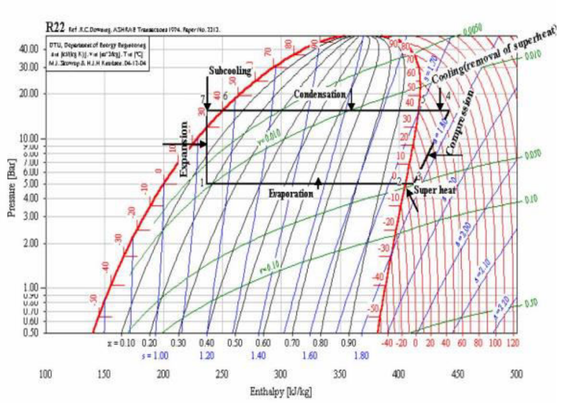

Figure-2. Pressure- Enthalpy diagram for vapour compression system.

1. Step 1-2-3: Absorption of heat by the liquid refrigerant and conversion to gas in the evaporator. Refrigerant is a substance with low boiling point at a desired working pressure. The surface of the evaporator is in contact with water for cooling. (From 1 to 2, liquid refrigerant absorbs latent heat energy, at constant pressure and temperature, converting itself to saturated vapour without increase in temperature; from 2 to 3, it absorbs additional heat at constant pressure to become superheated vapor with some increase in temperature. Superheating is necessary to prevent liquid refrigerant from entering the compressor).

2. Step 3-4: Compression of low temperature, low pressure refrigerant gas from the evaporator to high temperature, high pressure gas in the compressor. (From 3 to 4, reduction in vapour volume during compression, with increase in pressure; the joule equivalent of work done during compression increases the temperature of the vapour to level higher than ambient).

3. Step 4-5-6-7: Rejection of heat to the in the condenser, resulting in condensation of the gaseous refrigerant to liquid at high pressure. The condenser surface is cooled by moving air. (From 4 to 5, vapour temperature drops when superheat is removed and the vapour is saturated; from 5 to 6, saturated vapour condenses back to liquid phase at constant temperature and pressure; from 6-7, the liquid is sub-cooled below its saturation temperature).

4. Step 7-1: Expansion of the liquid refrigerant from high condenser pressure to low evaporator pressure through a throttling valve, called expansion device or valve. The opening of the expansion valve is controlled to enable capacity regulation. (There is no heat addition or removal during this process, but some flash gas is formed as a very small portion of the liquid refrigerant evaporates between the expansion valve and the evaporator. To reduce flash gas formation, condensers are sometimes giving more heat transfer area to sub-cool the refrigerant or a very small quantity of refrigerant is separately expanded in a sub-cooler to cool the liquid refrigerant before the expansion valve.)

The heat transfer rate in the evaporator influences the refrigerant suction temperature and pressure. The ambient conditions and heat transfer rate in the condenser influence the discharge temperature and pressure. The suction and discharge pressures, that is, the compression ratio basically decides the extent of work to be done by the compressor and hence the energy consumption in the compressor.

Since the compressor suction and discharge pressures are governed by the heat transfer in the evaporator and condenser, the heat transfer efficiency of these heat exchangers and the regulation of refrigerant flow through the system by the expansion valve and the performance of the compressor at partial loads plays a major role in deciding the overall operating efficiency of the vapour compression system.

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COMPRESSOR AND CAPACITY CONTROL

The compressors are constructed as hermetically sealed. In this motor-compressor unit, the entire assembly is encapsulated, only the refrigerant lines and electrical connections extend out of the housing. In hermetic compressors, the refrigerant is in contact with the motor windings. So only halocarbon refrigerants, which do not attack copper, are only be used.

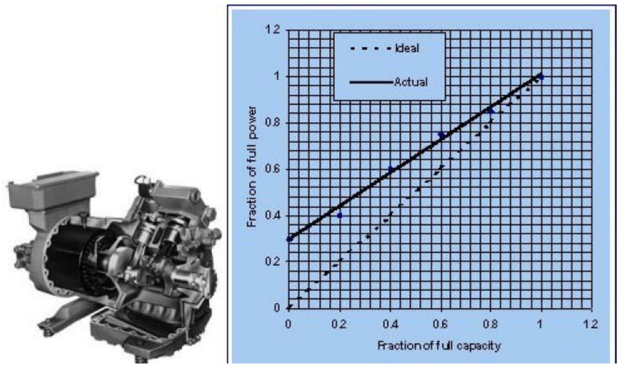

Figure-3. Reciprocating compressor.

In this chiller Reciprocating compressor is used, the refrigerant vapour is compressed by movement of the piston in a cylinder Figure. Reciprocating compressors are used as single machine capacities of 90 TR. Since it is the larger machines, the frequent starts and stops of motors are not possible, the capacity controls are adopted. In reciprocating compressors with multiple cylinders, cylinders are selectively loaded or unloaded, based on set pressures (reflecting the temperatures); the variation in power with cylinder unloading is shown in fig. 2.6. Unloading implies that the suction valve is kept open so that the vapour, taken in during the suction stroke, returns back through the suction valves itself during the discharge stroke.

EVAPORATORS

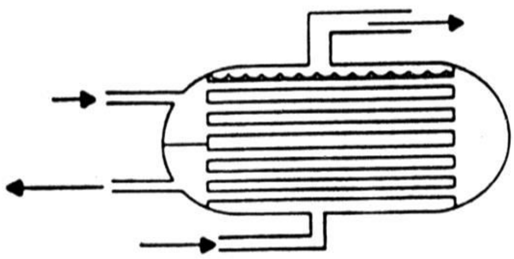

Figure-4. Heat exchanger evaporator.

The evaporator is the heat exchanger where the heat is removed from the system by boiling of the refrigerant in the evaporator. The heat is removed from water. The evaporator is a refrigerant cooled coil in an air stream (Air Handling Unit - AHU) for air conditioning

CONDENSERS

The condenser is the heat exchanger where the refrigerant gas condenses, giving up its heat to the atmosphere. The condensers is forced air draft cooled condensers.

SUB-COOLING

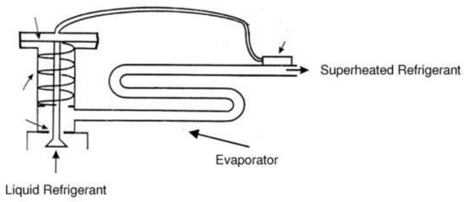

Figure-5. Schematic diagram of superheat sensing expansion valve.

Sub-cooling of the liquid refrigerant before the expansion valve reduces the flash gas formation and helps increase the evaporator capacity. The COP can improve by 5% to 10% by sub-cooling.

SUPERHEATING

Superheat is the increase in temperature of refrigerant gas above the evaporating temperature. The higher the suction gas superheat, lower the gas density and therefore, lower the compressor mass flow rate. This reduces the compressor capacity without reducing its power consumption, increasing running costs.

SECONDARY COOLANTS

In this chiller air is cooled through a secondary coolant. The Air handling unit (AHU) is connected to the chiller.

SPECIFIC POWER CONSUMPTION OF VAPOUR COMPRESSION SYSTEMS

The efficiency of refrigeration systems depends on the operating temperature and hence all figures of merit related to efficiency have to specified at a certain operating temperature. The COP of systems with air cooled condensers is generally about 20% to 40% higher. COSP (Coefficient of System Performance) is another parameter, which has been evolved to estimate the system performance by also including the power consumption of parasitic loads like fans, pumps etc.

OPERATION OF CHILLER PLANT

The Two numbers of chillers are commissioned and operated alternatively for every 24 hours.

Table-1: Name plate details.

S. No	Make: Blue star	Chiller 1	Chiller 2
	Unit model	L CAR - 090	L CAR - 090
	Unit Serial Number	2080-F2007	2080-F2007
	Compressor Model	JSB 3FT50B	JSB 3FT50B
	Compressor Serial Number	908614	903616
	Gas	R-22	R-22
	Normal Capacity	90TR	90TR
	Power supply	380-420V	380-420V
	Phase	3 phase, 50Hz	3 phase, 50Hz
	Speed	1440rpm	1440rpm
	Rated amps	184amps	184amps
	Large rated amps (LRA)	975amps	975amps
	Running load amps (RLA)	207amps	207amps

PERFORMANCE CHARACTERISTICS

Table-2. Step by step operating procedure.

Step	Switching "ON"	Switching "OFF"
1.	Air Handling Unit	Compressor Unit
2.	Water Pump Motor	Water Pump Motor
3.	Compressor Unit	Air Handling Unit

Table-3. Chiller load details.

Component	Load	I - r	I - y	I- b
	KW	Amps	Amps	Amps
Pump Motor	8.75	13.0	13.7	13.0
Return Pump 1	5.0	7.8	7.4	7.1
Return Pump 2	5.0	7.4	7.6	7.8
AHU 1	5.0	7.8	7.6	7.5
AHU 2	5.0	7.7	7.8	7.5
Condenser Motor 6nos	12.0	16.2	16.8	19.2
Compressor	99.20	184.0	183.0	181.0
Total	139.95	243.9	243.9	243.1

Table-4. Compressor current at various % loads.

S. No	Load in %	Current in Amps
1.	25	85
2.	50	114
3	75	147
4.	100	184

Table-5. Loads connected with the chiller feeder.

S. No	Equipment	Phase	Power
1.	Ventilation Motor	Single ph.	1.85 kW
2.	Deep Freezer	Single ph.	2kW
3.	1kVA UPS - 6nos	Single ph	5kW
4.	Staining machine	Single ph	1kw
5.	Auto Clave	Three ph	25kW

DETAILS OF AUTO CLAVE

Two autoclaves are available at the facility. They are essential for steam sterilisation of cages, top grills, water bottles, husk, etc before being supplied to the animals. Autoclaving is done at a temperature of 121 degree Celsius for 15 minutes at 15 pounds pressure. Materials for autoclaving are taken from the dirty corridor and after sterilisation, the materials are sent to the sterile material storeroom for further supply to the facility

The Autoclave consists of a resistive heater and the process control units of vacuum control, voltage control and gas control together with a PC workstation. The loads are modeled as generalised linear loads while the control units and the PC facilities as single-phase AC-DC static converters. The resistive heater can tolerate most power quality problems. However, the process controllers are very sensitive and it is reasonable to presume that some kind of network disturbances can cause the interruption of the process controller and can lead to the overall shut down of the Autoclave equipments during normal operation.

CONCLUSIONS

Various simulation models can be used to predict the performance of the reciprocating air-cooled chiller over a range of operating condition. The COP analysis and

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modeling of the reciprocating air-cooled chillers is studied. The COP of Chiller system decreases when the temperature is increased and at the same time the refrigerant effect is reduced. The real time switching transient is compared with simulation results.

ACKNOWLEDGEMENT

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APPENDIX
COMPRESSOR OUTPUT

S. No	Time		Discharge PSI	Pdischarge, bar	Discharge TEMP °C
1	9.00AM	78%	248	16.89833742	48
2	10.00AM	69%	248	16.89833742	48
3	11.00AM	70%	250	17.03461434	49
4	01.00PM	55%	252	17.17089125	50
5	06.00PM	66%	240	16.35322976	41
6	7.00PM	70%	235	16.01253748	39

AHU (Secondary Side)

S. No	Time		Water Inlet Kg/cm^2	Water TEMP	Water Outlet, kg/cm^2	Water TEMP	KW
1	9.00 AM	78%	19	3.8	5.9	10	388.74
2	10.00 AM	69%	18	4.0	6.0	9	313.5
3	11.00 AM	70%	17	4.0	6.0	8	250.8
4	01.00 PM	55%	16	4.0	6.0	8	250.8
5	06.00 PM	66%	16	4.0	6.0	8	250.8
6	7.00	70%	17	4.0	6.0	9	313.5

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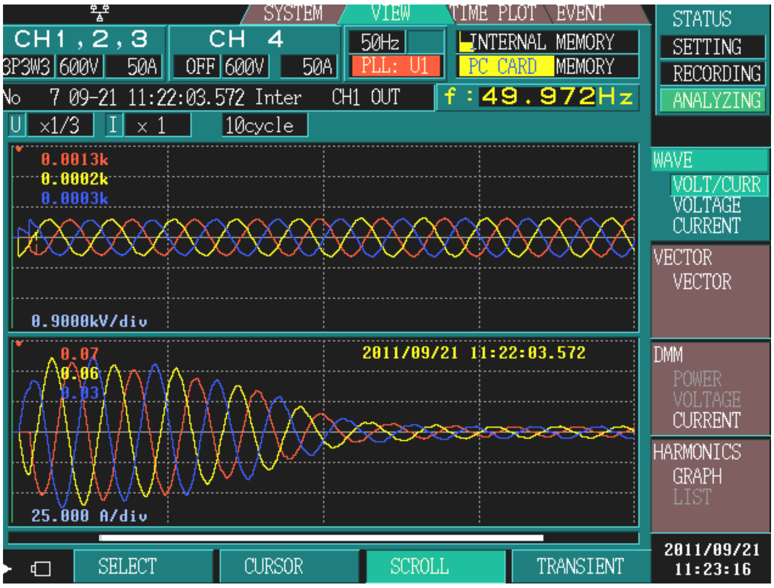
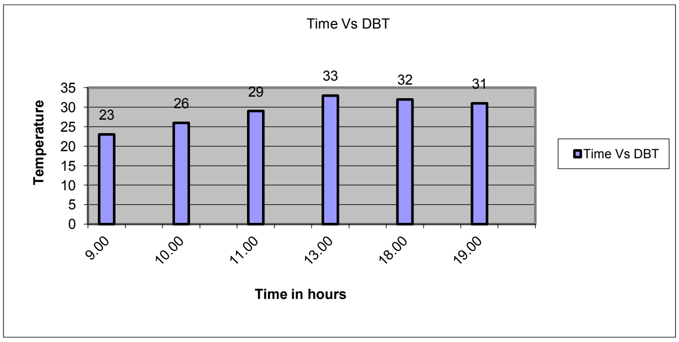
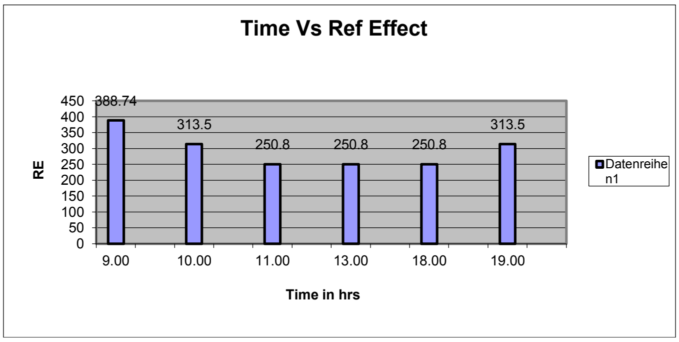
POWER QUALITY ANALYZER DATA OF TRANSIENTS



CHART





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